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FACTORS ASSOCIATED WITH LARGE VEHICLE COLLISION FATALITIES FROM 2009-2015, AN ASSESSMENT OF FACTORS RELEVANT TO THE 2014 IMPLEMENTATION OF THE NATIONAL REGISTRY OF CERTIFIED MEDICAL EXAMINERS AND STRATEGIES FOR DRIVER SAFETY

Melinda L. Carol
University of Kentucky, linn.carol@uky.edu

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Corrine Williams, ScD, MS, Director of Graduate Studies

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By
Melinda L Carol, M.D.
Honolulu, HI

Lexington, Kentucky

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David M Mannino, M.D.

Chair

Susan E Spengler, M.D, MSPH

Committee member

Timothy S Prince, M.D, MSPH

Committee member

Isabel Mellon, Ph.D.

Committee member

ABSTRACT

OBJECTIVE: The Federal Motor Carrier Safety Administration (FMCSA) developed a National Registry of Certified Medical Examiners (NRCME) as a stride toward greater driver safety and public health. This retrospective, observational, cross-section study is intended to trend and analyze driver related factors that are pertinent to FMCSA certifying medical examination performed by NRCME providers in addition to driver behaviors and environmental factors from the years 2009 to 2015. The results of this study are intended to speculate the effectiveness of the NRCME and propose additional public health interventions aimed to reduce large vehicle fatalities.

METHODS: Data was extracted from the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA). For each year from 2009 to 2015, data outputs were restricted to vehicles weighing over 10,000 lbs. The fields that were queried included: crash fields, vehicle fields, occupant fields, and driver fields. Within those fields, the outputs of interest were: speeding, crash hour, crash month, light condition, atmospheric condition, age, injury severity of the driver, extent of vehicle damage, commercial driver license (CDL) status, compliance with CDL restrictions, driver related factor regarding the use or failure to use medication/drugs, condition or impairment of the driver at the time of the crash (fatigue or illness related), the use of restraints, and whether an airbag had deployed. Data was analyzed for associations between the outputs of interest and year, driver injury severity, and vehicular damage using Pearson Chi-Square, Kruskal-Wallis H, and Mann-Whitney U tests. ANOVA was used to assess difference in drivers' mean age among years 2009-2015, driver injury severity levels, and vehicular damage. Pearson Chi-Square was used to determine an association between fatigue and daylight. Cross tabulations were used to look for proportional trends found among or between independent and dependent variables with statistically significant associations. Spearman *rho* was used to determine whether there was a linear relationship between daylight and fatigue. It was also used to assess the linear relationship between injury severity and vehicular damage.

RESULTS: The fatality rate was highest at 147.229 fatal large vehicle crashes per billion vehicle miles in 2015. The mean age of the drivers was not significantly different from 2009-2015. The mean driver age was highest for those who sustained fatal injury (48.66 years, $F = 2.232$, $p < .001$). From 2009 to 2015, the proportion of fatal accidents reported to involve speeding, fatigue, illness, and failed use of restraints had no statistically significant change over those years. Over those same years, the proportion of fatal crashes with reportedly fatigued divers ranged from 1.2-1.8%, those ill ranged from 0.4-0.6%, those speeding ranged from 21.7-23.4% and those with failed restraint use ranged from 15.7-17.5%. Drivers' misuse of medication or drugs were reported in only 3 cases in this study, revealing a significant reporting deficiency. Statistically significant associations, with greater than expected counts, were observed between fatal injury and: speeding, failed restraint use, driver fatigue, driver illness, invalid CDL status, and lighting conditions other than daylight ($p = .025$, $p < .001$, $p < .001$, $p < .001$, $p < .001$, $p < .001$, $p < .001$, respectively). Disabling damage had statistically significant associations with weather that was not clear, driver fatigue, driver illness, and invalid CDL ($p < .001$, $p < .001$, $p < .001$, $p = .004$, respectfully). A very weak linear relationship was found between lighting and fatigue (*rho*= .057, $p < .001$). A moderate linear relationship was present between driver injury severity and vehicular damage (*rho*= 0.422, $p < .001$).

CONCLUSIONS: Though likely underreported and underestimated, the proportion of fatal large vehicle crashes in relation to driver fatigue, medication misuse, and driver illness or blackout was minute. Whereas the proportion related to speeding and failed use of restraints was substantial. The FMCSA certifying medical examination is an intervention to ensure safe driving by preventing and restricting drivers with potentially incapacitating medical conditions. This study highlights the importance of addressing safety behaviors in addition to illness and fatigue. Adding a query about safety restraints and speeding to the FMCSA certified medical examination report form is an opportunity to provide a nationalized message of safety to commercial drivers, further promoting a culture of safety.

BACKGROUND

Long-haul truck drivers have highly stressful work environments. Internal pressures incentivize the fastest possible delivery schedule, particularly for drivers who are maximally compensated based on miles driven and speed of delivery. Their schedules often include night-shift work and inconsistent resting periods. Insufficient rest, nutrition, sleep hygiene, and exercise compromise the health of the driver, as a result, safety for the driver and the public are placed at risk (1, 2). The National Institute for Occupational Safety and Health (NIOSH) conducted a full survey of 1,265 long-haul truck drivers over 32 rest stops. The authors reported an estimated 73% of respondents perceived their delivery schedules as unrealistically tight; 37% reported being noncompliant with hours-of-service rules; 24% often continued driving despite fatigue, bad weather, and heavy traffic; and 15% did not feel that the safety of workers was a high priority with their management (3, 4). A climate of safety is lacking within the trucking industry. The monotony of driving and the time-pressure of delivery deadlines create sleep-related fatigue, active task-related fatigue, and passive task-related fatigue. Fatigue and reduced states of wakefulness during road driving are associated with a preventable portion of motor vehicle accidents (5-9).

In further effort to increase the quality of commercial driver medical examinations, thus increasing the public's confidence in road safety, the Federal Motor Carrier Safety Administration (FMCSA) announced the development of a National Registry of Certified Medical Examiners (NRCME) on April 18, 2012 (10). Another goal of the initiative was to ensure that medical examiners are fully aware of the FMCSA standards and maintain ongoing competency through training, testing, and recertification (10).

Commercial motor vehicle drivers have required certificates of physical examination since January 1, 1954. Any driver of a vehicle with a gross-weight exceeding 10,000 lbs. is required to acquire a certificate of medical examination. This certificate of medical examination must be renewed at least every two years. As of May 21, 2014, only examiners who have been trained and certified in accordance with the FMCSA's NRCME would be able to perform the Commercial Driver Medical Exam (CDME, commonly referred to as the "DOT examination").

The risks derived from long-haul truck driving are a national burden. The productivity losses, property damage, medical costs, rehabilitation costs, travel delay, legal fees, emergency responder services, insurance costs, and costs to employers amounted to a financial loss of an estimated $99 billion in 2012 (3). Heavy truck and tractor-trailer truck drivers were twelve times more likely to die on the job and three times more likely to suffer an injury involving days away from work than the general U.S. worker population (2). The U.S. Bureau of Labor Statistics' Census of Fatal Occupational Injuries reported 396 fatalities among heavy truck and tractor-trailer truck drivers in 2010 with a rate of 31.8 per 100,000 workers; this is ten times the overall fatality rate of in-house workers (11). Numerous studies in the literature endorse the contributory roles of individual-based and environment-based factors in large truck collisions and fatalities. Driver sleepiness/fatigue, distraction/inattention, age greater than 50, and non-use of safety belts increase the odds that a commercial vehicle collision will be fatal (8). Proposed external factors include: long hours of driving and non-driving work, tight delivery schedule, being paid by-the-mile/kilometer, driving in poor weather conditions, and road traffic conditions (3, 12, 13).

The Federal Motor Carrier Safety Administration (FMCSA) released their final rule Hours of Service (HOS) regulations for all U.S. commercial motor vehicle drivers in 2011, and took full effect on July 1, 2013. These regulations penalize non-compliant drivers, rather than solely the businesses that may insufficiently compensate compliant employees, thus discouraging driver compliance with the FMCSA ruling. By limiting driving to 11 hours per work day; drivers may have to drive at faster speeds and/or take fewer brakes in order to maintain their required delivery requirements. Furthermore, when it comes to HOS, there are no reliable surveillance and enforcement systems that assure compliance. Drivers' log books are self-produced, reporting non-compliant hours may result in a fine for the driver, hence discouraging honest reporting.

The need for intervention is apparent considering the high number of collision fatalities per year. This study assesses the fatality rates from 2009 to 2015; 2015 is the year after the implementation of the NRCME. When formulating public safety interventions, it is important to assess factors associated with the adverse outcome. This retrospective, observational, cross-sectional study is intended to trend driver related factors that are pertinent to the Department of Transportation (DOT) certifying medical examination, driver behaviors, and environmental factors from 2009 to 2015. The association of these factors with driver injury severity and vehicle damage will also be examined. The results of this study are intended to inspire and propose additional public health interventions aimed to reduce large vehicle related fatalities.

METHODS

De-identified data were taken from the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration (NHTSA). Microsoft Excel spreadsheets were downloaded after querying FARS each year from 2009 to 2015. For each year, data outputs were restricted to vehicles weighing over 10,000 lbs. The fields that were queried included: crash fields, vehicle fields, occupant fields, and driver fields. Within those fields, the outputs of interest were: speeding, crash hour, crash month, light condition, atmospheric condition, age, injury severity of the driver (limited to person type 1, the driver), extent of vehicle damage, commercial driver license (CDL) status, compliance with CDL restrictions, driver related factors, condition or impairment of the driver at the time of the crash, the use of restraints, and whether an airbag had deployed. All categorical data are assigned numerical values in FARS. Microsoft Excel outputs were download; all values were subsequently transferred from Microsoft Excel into an SPSS 24 data set.

After the data was transferred into SPSS 24, numerical categorical values were transformed, to narrow categories to fewer or dichotomous variables, such as: light condition (daylight or other), atmospheric condition (clear weather or other), CDL status (valid or invalid), compliance with restrictions (compliant or not compliant), restraints (restraint used or not used), and airbag deployed (airbag deployed or not deployed). The factor, "the condition/impairment of the driver at the time of the crash" was transformed and filtered to limit the categories to: [none/apparently normal or asleep/fatigued] and [none/apparently normal or ill/blackout]. Similarly, "driver related factor" was filtered to "reaction to or failure to take drugs/medication" or "none/normal." Missing values were imputed using proximal interpolation for nominal variables. Linear interpolation was used to replace missing values within ordinal data and the median was used for missing continuous values. Responses of "unknown", "not reported", "not applicable", "other", and "blank" were given a transformed value of "0" and subsequently excluded from the analysis and not included in tables or figures.

Data regarding the extent of injury of the driver and vehicle damage were transformed in an ascending ordinal fashion. The injury severity levels were 1) no injury, 2) possible injury, 3) injured, severity unknown, 4) non-incapacitating injury, 5) incapacitating injury, and 6) fatal injury. Vehicle damage values were assigned as follows: 1) no damage, 2) minor damage, 3) functional damage, 4) disabling damage. The data in FARS does not have an option that enables distinction between short-haul and long-haul drivers.

The Bureau of Transportation Statistics was used to determine vehicle miles per year. For each year, from 2009 to 2015, the million vehicle miles for vehicles weighing over 10,000 pounds were determined by adding the miles reported for "single-unit-2-axle-6-tire or more" with the miles of "combo-trucks" and "busses." These values were converted to billion vehicle miles and used as the denominator when trending the rate of large vehicle fatalities from 2009-2015.

The average age of the driver per year spanning 2009-2015 was evaluated for variance using one-way ANOVA. ANOVA was also used to determine whether there was a significant variance in the mean age of the driver among the various levels of injury and vehicle damage. A significant ANOVA was followed by a post-hoc analysis using Tukey's HSD to determine the nature of the difference.

Cross tabulations were performed to trend the proportion of fatal crashes involving speeding, fatigue, illness, failed use of restraints, deployed airbags, invalid CDL, compliance with CDL restrictions, and the use or failure to use medications/drugs for each of the years of 2009 through 2015, levels of injury severity, and the extent of vehicle damage. Goodness of fit and analysis of independence were examined using Pearson Chi-Square. Those same variables were used to cross-tabulate and graphically trend proportions based on injury level of the driver and the extent of vehicle damage. Microsoft Word was used to create stacked bar and line-with-marker charts. Mann-Whitney U tests were used to determine whether associations were present between categorical unpaired variables and ordinal injury severity and extent of damage. Pearson Chi-Square test was used to evaluate the presence of associations between nominal variables, fatigue and lighting. Spearman *rho* was used to determine whether there was a linear relationship between daylight and fatigue after the data had been transformed into dichotomous variables (1 = daylight, 2 = all other darker conditions and 1 = none/normal and 2 = fatigued). Kruskal-Wallis H test was used to determine whether years 2009-2015 were equal in regard to injury severity of the drivers and the extent of damage to the involved vehicles.

Non-parametric tests do not have post-hoc analyses. Cross tabulations were used to look for proportional trends found among or between independent and dependent variables; the expected and observed case counts were reviewed after a statistically significant relationship was determined by either Mann-Whitney U or Kruskal-Wallis H tests. Variables with salient proportional differences between expected and observed counts were included in the tables.

Variables were selected a priori on the basis of factors thought to influence the severity of injury and vehicle damage. All tests are two-tailed, and p values less than 0.05 indicate statistical significance.

RESULTS

Fatal Crash Rates 2009-2015

From 2009 to 2015 there were 27,741 vehicle collisions involving a large vehicle weighing more than 10,000 pounds. During that interval, a total of approximately 204.845 billion miles had been driven by large vehicles (table 1). An upward trend of the rate of vehicle crashes per billion vehicle miles was observed from 2009 to

2013. In contrast, a 6% decrease in the rate occurred in 2014. The upward trend was restored in 2015, greater by 1.7% from the rate during 2013 and increasing by 8% from the rate during 2014 (figure 1).

Age

The mean age of the driver ranged from 49.15 to 51.21. A slight upward trend in the mode age (range = 46-55) was seen from 2012 to 2015 (table 1). The median age was steadfast from 2009 to 2015, ranging from 46 to 48. Means were compared using ANOVA and no significant difference was determined $p = 0.772$. When ANOVA was performed on mean age of those at each level of injury, compiling data from 2009 to 2015, a significant difference in mean age was appreciated, $p < 0.001$ among the injury levels. On post-hoc analysis using Tukey's HSD to determine the differences between mean ages per paired injury level, no significant differences in mean age were found for levels 1 though five. However, those who sustained a fatal injury, level 6, had a statistically significant greater mean age compared to lesser levels of injury 1, 2, 4, and 5, ($F = 2.231$, $p < 0.001$) (table 3). When analyzing the differences in mean age with among levels vehicular damage using ANOVA, another significant difference was found ($F = 4.195$, $p < .001$). Significant difference in mean age was found between those that sustained no damage (1) and those that sustained function damage (3) ($p = 0.036$); those that sustained minor damage (2) to those with disabling damage (4) ($p = 0.024$); and those that sustained functional damage compared to those with disabling damage ($p < 0.001$). The drivers in crashes that caused disabling damage were older than those involved in crashes that caused minor damage or functional damage. However, there was no difference in mean age when comparing the no damage group (1) with the disabling damage group (4).

Factor Comparisons by Year, 2009-2015

The proportion of factors of interest were plotted to assess whether changes in trend have occurred over time. Throughout all seven years there were three cases that documented a collision due to using or failing to use drugs or medication (figure 2, table 2); one in 2010, one in 2013, and one in 2014. Chi-Square tests of independence were calculated comparing the association between the year of the crash and the factor of interest. Scant amount of collisions documented illness of the driver, the proportion ranged from 0.4-0.6%, no significant relationship was found ($X^2 = 10.725$, $p = 0.773$). Fatigue was also a minor factor that did not significantly differ from 2009 to 2015, ranging from 1.2-1.8% ($X^2 = 10.725$, $p = 0.772$). Airbags were rarely deployed, only deploying in 3-5.1% of cases; however, a significant interaction with year was found ($X^2 = 27.081$, $p < 0.001$). The lowest proportion of crashes with a deployed airbag was in 2009.

Of those with CDL restrictions, restrictions were not complied with in 7.6-8.3% of fatal collisions. An interaction was found, a significant decrease in the proportion of those who were not compliant was seen in 2015 ($X^2 = 35.932$, $p = 0.007$), which is the year after the implementation of the NRCME. The proportion of those documented as not having a valid CDL ranged from 13.1-15.2%, a significant interaction was found (X^2= 13.006, p = 0.043); the year with the lowest proportion was 2014, the highest was in 2012. There was no significant interaction between year and the use of restraints (X^2= 8.030, p = 0.236). Restraints were not used in 15.7-17.5% of cases from 2009-2015. Similarly, no interaction was observed in regard to speeding which occurred in 21.5-23.4% of collisions each year from 2009-2015 (X^2= 8.067,p = 0.233). Insufficient use of restraints and speeding seem to be at a steady state from 2009 to 2015.

Using Kruskal-Wallis H analysis, a relationship between year and the levels of injury severity of the driver was appreciated (tables 4, 5, and figure 6). A significant result (H(6) = 31.030, p<.001) indicates that at least one group year differed from the others within the six levels of driver injury. Since 2011, the observed number of fatally injured drivers has exceeded the expected estimate. In 2015, the observed number of drivers that were uninjured exceeded the expected by the largest proportion (3.26%), compared to years 2009-2014.

In addition to injury severity, the severity of vehicle damage differed among years. At least one year within 2009-2015 significantly differed from the rest in regard to the extent of damage to the vehicles (H(6) = 23.177, p <.001) (tables 6, 7, and figure 7). The observed number of disabled vehicles were less than expected each year from 2009 to 2014. In contrast, in the year 2015, the number of disabled vehicles was 7.13% higher than expected. Moreover, the count of vehicles without damage was 12.80% lower than expected. In sharp contrast, during 2009 vehicles without damage exceed the expected figure by 17.04%.

Injury Severity

Figure 3 represents the proportion of each covariate of interest, y-axis, by the severity of injury, the x-axis. Mann-Whitney U tests were conducted to compare injury outcomes with the factors: speeding, deployed airbag, driver illness, restraint use, driver fatigue, CDL status, compliance with CDL restrictions, atmospheric/weather conditions, and lighting conditions. A significant difference among the severity of injury for those that were speeding compared to those that were not speeding was observed (U = 42292406.0, p = 0.025, fatal injures expected = 907, observed = 984 (+7.82%)). For those who were speeding, the count of fatal injuries exceeded the expected if all outcome probabilities were equal (table 4).

Airbags are designed to reduce injury severity. In 95.6% of crashes, an airbag was not deployed or the vehicle was not equipped with airbags. A significant (U = 5581357.5, p <0.001) difference was observed, cross tabulation determined that the observed count of deployed airbags was greater than expected by 65.99% when an incapacitating injury occurred. A Mann-Whitney U test supports a dependent relationship. It should not be inferred; however, that air bag deployment promotes incapacitating injury, n=919, a larger n is needed. When it comes to vehicular safety features, restraint belts are paramount. Figure 3 shows a salient increase in the proportion of unrestrained drivers who were fatally injured; a dependence was determined ($U = 14262385.0$, $p < 0.001$). Observed counts of unrestrained drivers with a mortal injury exceed the expected by 66.03%, supporting the importance of the use of seatbelts to prevent fatalities.

Only three cases documented that the driver was affected by the use or the failure to use drugs or medications, one in 2010, one in 2013, and one in 2014. Two of the three cases reported possible injury; the case in 2010 reported the driver as not injured. Medication and illness often co-exist. Illness was reported in 112 cases. The ratio between illness and medication use is out of balance. This suggests that medication use, or failure to use, has been alarmingly underreported. Those with fatal injuries were documented as "ill" or "blackout" at an observed count that was 73.61% greater than expected ($U = 538534.5$, $p < .001$, n= 112, n is too small for definitive conclusion). Those with fatal injuries are unresponsive and may have been misclassified.

A small proportion ranging from 0-0.5% was observed for those who were reportedly non-compliant with their CDL restrictions, n= 120 (table 4, figure 3). Mann-Whitney U test indicated that the groups did not differ significantly from each other ($U = 56680.0$, $p = .997$). A significant difference was found in drivers' injury severity between those with a valid and invalid CDL ($U = 20535862.0$, $p < .001$); the observed count of fatally injured drivers without a valid CDL exceeded what would be expected by 23.60%.

Atmospheric conditions are unpreventable potential contributors to collisions. Clear weather was reported in over 61.04% of cases in this study. When comparing the injury severity of the driver between those that drove in clear weather to those that drove in poorer weather, no significant difference was found ($U = 42292406.0$, $p = .772$). Limited lighting is another external factor that adds difficulty for drivers. A difference was found of at least one level of injury from the other levels in regard to daylight ($U = 46669684.5$, $p < .001$). The observed count of fatal injuries was slightly greater by 1.99% than anticipated when collisions occurred before or after daylight. Histograms show (figures 4 and 5) that the greatest percentage of fatal crashes from 2009-2015 occurred between the hours of 0500 and 1800 hours; the mode was at 1400 hours and the median was 1200 hours. The months with the highest percentages were May through December. October was the mode month and July was the median. Darker light conditions may have a small, yet significant, influence on injury severity, but not on the number of total fatal collisions.

Melatonin is a hormone secreted by the pineal gland in response to darkness, inducing sleepiness (14). For this reason, the relationship between daylight and fatigue was investigated using Pearson Chi-Square analysis for independence. The frequency of fatigue was calculated for those involved in a fatal collision who were exposed to daylight or other darker outdoor lighting. A statistically significant interaction was found (X^2= 68.498, p < 0.001. Lighting and fatigue appear to be dependent events. Actual counts of those fatigued in associated with darker light conditions exceeded what would be expected (+35.93%). A very weak linear positive correlation was deduced (*rho*= .057, p< .001) between fatigue and daylight.

Driver fatigue was rarely documented, ranging from 0.5-5.5% among the various injury severity ratings. Though rare n= 354, at least one level of injury severity significantly differed from the others in the fatigue group (U = 1611958.5, p <.001). A larger sample size is needed to support the association. The observed number of fatal injuries that documented the driver as fatigued was 73.77% greater than expected.

A linear relationship between injury severity and the extent of vehicle damage among reported fatal collisions from 2009-2015 was investigated (table 7). Spearman *rho* was calculated that indicated a statistically significant moderate positive correlation (*rho* = .422, p < .001).

Extent of Vehicle Damage

A greater proportion of adverse weather was involved as the level of damage increased (table 7, figure 8). A Mann-Whitney U test assumes that all groups have the same distribution. A significant result was calculated, indicating that there was a difference in the extent of vehicle damage dependent upon the weather condition (U= 40411878.5, p<.001). The greatest proportional difference seen in cross tabulation was that of disabling damage and weather that was not clear; the observed count was 4.4% above the value of the expected. A relationship between speeding and the extent of damage was also appreciated (U= 36543198.5, p = .016). On cross tabulation, the observed count was 13.3% greater than the expected for drivers who were not speeding to have vehicles that were reportedly not damaged.

Just as it was for injury severity, there was no statistical significance in the extent of vehicle damage between those who were compliant and those who were not compliant with their CDL restrictions (U= 67920.0, p = .700, n=67). The extent of vehicle damage; however, was significantly different between drivers with valid CDLs and drivers without valid CDLs (U= 35196104.0, p= .004). The count of disabling damage for a driver without a valid CDL was 4.1% greater than expected.

Driver fatigue had a significant effect on the extent of vehicle damage (U= 2590601.0, p< .001). The observed count of cases of disabling damage that reported the drivers to be fatigued was 30.8% higher than expected. In contrast, the observed count of cases with disabling damage that reported the drivers as normal was 3.3% lower than expected. Another driver-centric factor, illness, had significant association with the extent of vehicle damage (U= 890297.0, p< .001, n= 112). The drivers that were documented as ill or “blacked out” at the time of the crash had an observed count that was 25.93% higher than expected. There were only three cases of fatal large vehicle collision with a report of the use or failed use of medications or drugs as a factor; too few to compute an association. However, each of the three cases reported disabling vehicular damage.

An association between daylight and darker conditions was found to be significantly different among the levels of vehicle damage ($U = 56023187.5$, $p < .001$). During daylight, the observed crash count with disabling damage was 3.6% greater than expected while the observed crash count with no damage was 12.2% lower than expected. The opposite trend was found under darker outdoor light conditions.

DISCUSSION

The FARS database is a census of all U.S. fatal crashes that result in the death of a motorist, other vehicle occupant, or non-motorist within 30 days after occurrence of the motor vehicle accident. FARS data are collected and coded by specially trained state analysts from police accident reports (PARs) and related documents (15). Inter-observer reliability among analysts has not been studied. Furthermore, the police accident reports are dependent upon the experience and training of the reporting officer. Inter-observer reliability and variability among police officers is unknown. The collected data is often subject to variable interpretations, such as the definition of "fatigue." The data is FARS data cannot sufficiently infer causality; however, it is valuable in the study of associations. FARS data supplemented with The Trucks Involved in Fatal Accidents (TIFA) and Busses Involved in Fatal Accidents (BIFA) databases provide more accurate and detailed information; such an inclusion would add strength to this study. TIFA and BIFA surveys involve retrospective interviews with drivers, police officers, emergency personnel, and witnesses. Greater depth retrospective crash investigations; however, have the same fundamental shortcoming, they are after-the-fact reconstructions that may underestimate or overestimate results secondary to recall bias and misclassification.

In this study, fatigued drivers sustained more fatal injury counts than expected ($p < .001$). The results presented are consistent with a case-control study performed by Bunn et al. that found that drivers with sleepiness/fatigue and drivers without use of seatbelts had a higher likelihood of sustaining a fatal versus a nonfatal injury (16). In FARS, fatigue was reported in only 1.2-1.6% of fatal crashes from 2009-2015, with no statistically significant change over time.

Another limitation of FARS data is the inability to analyze between long and short-haul drivers. It is possible that fatigue in short-haul drivers is vastly less, creating a gross underestimation of the effect from fatigue on long-haul driver fatal collisions. Though seemingly small, this study does highlight the importance of the association between fatigue and fatal injury of the driver ($p < .001$); however, the small sample size ($n = 360$) makes the interpretation dubious.

Targeted surveys of long-haul truck drivers have provided valuable insights into the contributory role that fatigue plays in fatal motor vehicle crashes. Sieber et al. analyzed completed interviews from 1265 long-haul truck drivers at 32 truck stops across 48 states in 2010. Prevalence data were sex and age adjusted and compared to the 2010 National Health Interview Survey. Thirty-four percent of the 1265 participants reported nodding off/falling asleep/drowsiness while driving at some point within their professional driving career; 7% reported this to be almost every day during their driving run (17). The reported sleep and work behaviors were concerning; 62.9% slept at home less than 7 days in the past 30 days (18.3% had 0 out of 30 days), 77.9% reported getting an average of less than 8 hour of sleep in a 24-hour period (26.5% reported less than 6 hours), the average hours worked in the last 7 days were 60.4, and 42.9% usually drove for at least 5 hours before stopping for fuel or a break (17). The Hours of Service (HOS) regulations (49 CFR, Part 395) permit commercial long-haul driving for 11 straight hours and up to 70 hours per week. This rule may be insufficient to improve driver alertness, drowsiness, and fatigue issues (15).

Those with a history of one DOT recordable crash and those with 2 or more were 23% and 12%, respectively (3). Moreover, 24% reported at least one near miss vehicle collision in the past 7 days. Of that 24%, 12% reported two or more near misses (3). Mean Epworth Sleepiness Scale was 9, 15% were above this value (17). This survey study suggests that the percentage of fatigue reported in FARS is vastly underreported, underestimated, and in need of subset measures to better standardize the definition of fatigue.

The NRCME was designed to decrease the potential for sudden driver incapacitation. Chronic medical conditions that can lead to sudden incapacitation include uncontrolled hypertension, diabetes, and epilepsy within the past ten years. BMI is sometimes used as an estimate of driver health due to the strong association of obesity with hypertension and diabetes (17). The evaluation of BMI was not included in this study. Weight was recorded consistently in FARS; however, height was most often documented as either 5 or 6 feet, making BMI calculations indiscernible. The vague category of "illness/black-out" was assessed and a significant association with injury severity and vehicle damage was found. Those that were reported as ill or blacked out had higher counts of fatal injury and disabling vehicle damage than anticipated ($p<.001$, $p<.001$). Loss of consciousness due to the severity of the crash may have prompted erroneously labeling. The small group size ($n= 112$) is another issue that adds caution to the interpretation. However, the statistic is consistent with data presented by Thiese et al. that showed a small proportional increase in crashes with fatalities when the driver had 2 medical conditions compared to those with 0 or 1 (18). However, small sample size was a limitation in their study as well, regarding the relationship between poor health and fatal motor vehicle collisions. Interestingly, the use or failure to use medications was reported only thrice in FARS from 2009 to 2015. "Use or failure to use medications or drugs" was placed in the "Driver Related Factors" category. The other codes within this category are mostly referent to drivers' technical or judgement errors that contributed to the collision. "Use or failure to use medications or drugs" seems out of place in its current category and was likely repeatedly overlooked. Better documentation may occur if it were put in the relevant category of, "condition (impairment) at the time of the crash." Inappropriate use of medications may have a stronger role in injury severity than the number of drivers' medical conditions; this is an area that is in need of further study.

Limitations were many. This retrospective cross-sectional review cannot establish temporal relationships. Temporality is key to causality; thus, this study cannot establish cause and effect. As previously discussed, FARS data is limited by its retrospective nature; it relies on analysts and police reports with questionable accuracy and consistency.

The injury severity and extent of damage levels that are recorded in FARS are based on the first 30 days from the accident. Those with perceived incapacitating injuries may recover and those perceived to have non-incapacitating injuries might have delayed complications. This non-differential misclassification would bring the association of intermediate driver injury and vehicle damage levels closer to the null.

Highly unequal paired groups in this analysis included illness, fatigue, and drivers who were non-compliant with their restrictions. The associations found in groups with small numbers may be significantly different with larger sample sizes.

The non-parametric data in this study can be used to assess whether an interaction is present; unfortunately, a reliable post-hoc analysis cannot be done to determine the direction and magnitude of the interaction. In addition, this model is observational and confounding is plentiful. Lancaster et al. identified 16 individual human factors that contributed to driving. Of those 16 factors, this study only looked at fatigue and age. Other factors include gender, education, personality, aggression, thoroughness in decision-making, driving confidence/experience, attitudes, risk perception, social deviance, experience with previous motor vehicle accidents, stress, life events, physiology, and ethnicity (19). Long-term human factors confound short-term factors and vice versa. Factors that reduce driver capabilities on a long-term basis such as experience, aging, disease and disability, alcoholism, and drug abuse can be difficult to distinguish from short-term, transient issues such as drowsiness, fatigue, acute alcohol intoxication, short-term drug effects, acute psychological stress, and temporary distraction (20). A modifier may be the number of miles driven and hours worked per shift. FARS does not have an option to distinguish between vehicles weighing over 10,000 pounds that are operated short-haul versus long-haul. The associations observed in this study may be significantly different between short-haul and long-haul drivers.

Weather that was 'other than "clear"' did not significantly influence injury severity but it did significantly increase the proportion of vehicles that sustained disabling damage ($p<.001$). The significant independent variable may be the "road condition" rather than the "weather." Analysis of road-related conditions was lacking in this study. The estimated comprehensive cost of traffic crashes where road conditions contributed to crash occurrence or severity was $217.5 billion in 2006 (21). Road upgrading and maintenance play an important role in preventing and reducing damage and injury severity of a crash. Road improvements include structural changes, widening shoulders, improving roadway alignment, replacing or widening narrow bridges, reducing pavement edges or drop-offs, and providing more clear space in the area adjacent to roadways (22). Cost-effective, immediate solutions include using brighter, more durable pavement markings, installing easier-to-read signs, adding rumble strips, and using guardrails or barriers where appropriate (23).

A strength of the study is its generalizability; data from all 50 states were included. The database is nationally accessible, making this study reproducible. A large number of cases were included; this study was reasonably powered. Observational cross-sectional studies like this one incite future research and interventions.

This study demonstrated that speeding and the lack of restraints significantly and persistently contributed to the severity of injury. The contribution of speeding and lack of safety restraints has not significantly changed from 2009-2015 ($p<.001$). Speeding is one of the most important factors in traffic safety as higher speeds are linked to higher crash risk and higher injury severities (24). This study found a moderate positive correlation between injury severity and vehicle damage ($p<.001$). Hence a reduction is speeding leads to a reduction in the financial burden of crash related injury and property damage.

The proportion of speeding has not significantly changed as determined by FARS data extracted from 2009 to 2015. Additional intervention is warranted. Variable speed limit controls and integrated cooperative adaptive controls for reducing rear-end collision risks are being developed and studied in China as a potential preventive measure against speeding related motor vehicle accidents (25). Nearly a third of fatal crashes in the United States are designated as "speeding-related" (24). The data extracted during this study was consistent with that statistic. In sharp contrast, fatigue, a well-studied and agreed upon factor that may potentiate collisions (6, 8, 17, 19, 26), was rare in this study.

Troxel et al. performed a systematic review of 24 studies, 18 found a significant association between whole-body vibrations (WBV) – generated from large truck driving- and fatigue. Decrements in psychomotor performance were also appreciated after WBV exposure (27). External factors, such as WBV, are beyond the control of the driver and may exacerbate or incite fatigue. Our study showed that darker lighting, another uncontrollable external factor, had a significant association with fatigue ($p<.001$) with a very weak positive correlation. Fatigue is induced by both extrinsic and intrinsic factors; therefore, a successful intervention must address both. Medical examinations from FMCSA registered providers assess medical conditions and medications that cause or potentiate additional fatigue; they address internal driver related factors. Interventions that address external factors may have a greater impact in the overall reduction of fatal large truck motor vehicle collisions; considering external factors are in greater proportion. Extrinsic interventions such as Hours of Service (HOS) regulations that ensure adequate recovery from fatigue and engineering controls such as improved lighting would be of benefit.

Endeavors focusing on administrative and environmental controls rather than personal-level factors may reduce large-vehicle accident morbidity and mortality by a large proportion. Emerging crash avoidance technologies for large trucks include: vehicle stability control (VSC), side view assist, forward collision warning/mitigation, and lane departure warning/prevention. Of these four developing technologies, side view assist was determined to have the greatest potential for preventing large truck crashes of any severity based on a the high prevalence of side-to-side crashes among large trucks (28). Truck side impacts (side-to-side and oblique/same direction) produced injuries with greater severity to passenger vehicle occupants; the installation of large truck side underride guards has been initiated (29). Electronic stability control (ESC) of passenger cars has been studied in Sweden. Strandroth et al. reported a 32% reduction in fatal crash injuries on snow or ice covered roads compared to equivalent vehicles without the technology (30). ESC systems use automatic computer controlled breaking of individual wheels to assist the driver in maintaining control in critical driving situations in which the vehicle is beginning to lose directional stability at the rear wheels (spin out) or directional control at the front wheels (plow out)(31). A study of passenger vehicles in California found that ESC was effective in reducing loss of control moments that lead to certain rollover crashes; however, its effectiveness diminished when the vehicle departed from the roadway and during slick road conditions. In addition, the usefulness was limited when the driver was speeding, distracted, fatigued, or overcorrected the wheel (31). Hence certain driver behaviors are needed in order for many protective features to work as intended.

There is essentially unanimous agreement among truck safety studies about the quantitative benefits of using safety belts (15). This study is consistent with that agreement. A higher proportion of unrestrained drivers sustained fatal injuries compared to those that were restrained. Furthermore, the proportion of unrestrained drivers did not significantly vary from 2009 to 2015; suggesting the need for ongoing driver education. Safety belts cannot protect without drivers' complicity. The use of front air bags in combination with safety belts can provide additional protection by reducing the contact force between the steering wheel and the driver's torso (32). In addition, to preventing ejection of the occupant, safety belts prevent or reduce the severity of interior impacts (15). Simultaneous use of both safety belt and air bag limited the forward excursion and reduced occupant injury level, while an air bag without a safety belt allowed for greater forward chest and lower extremity displacement, resulting in higher femur loads (15). This again outlines the importance of drivers' behaviors and attitudes to optimize external safety features.

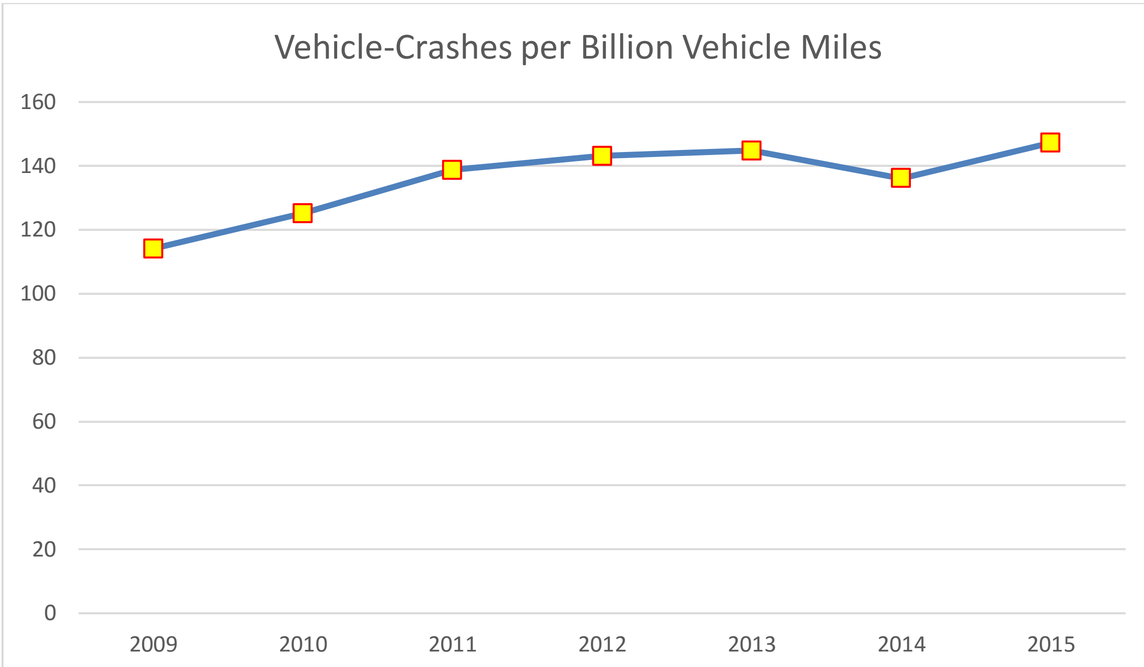
The FMCSA was authorized to establish a National Registry of Medical Examiners. It rejects driver medical examinations performed by providers that are not in the registry. In addition, there are regular reviews of a select number of submitted driver medical examinations to ensure that FMCSA standards and guidelines are maintained (15). This is an important stride in driver safety and public health. However, the success is dependent upon the truthfulness of the driver. Drivers' primary care providers (PCPs) have access to their medical records, enabling PCPs to make best practice decisions based on drivers' medications and medical histories. However, that PCP may not sufficiently know the FMCSA standards that have been established through expert panels and peer-reviewed research. Similar to regular visits with drivers' PCPs, the Department of Transportation "medical examination report form" queries drivers' medical history and substance use. There is an opportunity that may increase driver safety that is often included in a visit with a PCP, but is lacking in the current FMCSA certified medical exam. That opportunity is the assessment of driver safety behaviors, such as the use of seat belts, and assessing drivers' knowledge of the dangers of speeding, and subsequently educating accordingly. Speeding and the lack of restraints were two factors in this study that have significant association with injury severity and have had no significant improvement in proportions of fatal large vehicle accidents from 2009 to 2015. Of 1265 surveyed professional truck drivers, 15% did not feel that safety of workers was a high priority with their management (33). The FMCSA certifying medical examination is an opportunity to bridge the gap and promote a culture of safety. Adding a query about safety restraints and speeding to the FMCSA certified medical examination report form would provide a nationalized message of safety to all commercial drivers.

APPENDIX

Table 1

Year	2009	2010	2011	2012	2013	2014	2015	Total
Number of vehicle collisions	3455	3760	3897	4052	4201	4017	4359	27,741
Billion Vehicle Miles	30.269	30.030	28.100	28.307	29.019	29.513	29.607	204.845
Number of Vehicle Crashes per billion vehicle miles	114.143	125.208	138.683	143.145	144.767	136.110	147.229	
Mean Age of Driver	51.06	51.21	49.15	49.77	50.83	50.38	50.17	
95% Confidence Interval	(48.74-53.39)	(48.96-53.46)	(47.51-50.78	(47.95-51.60)	(48.91-52.74)	(48.54-52.22)	(48.42-51.92)	
						F = 0.548	p = 0.772	
Median Age	46	47	47	47	48	48	47	
Mode	46	48	51	50	48	51	55	

Figure 1

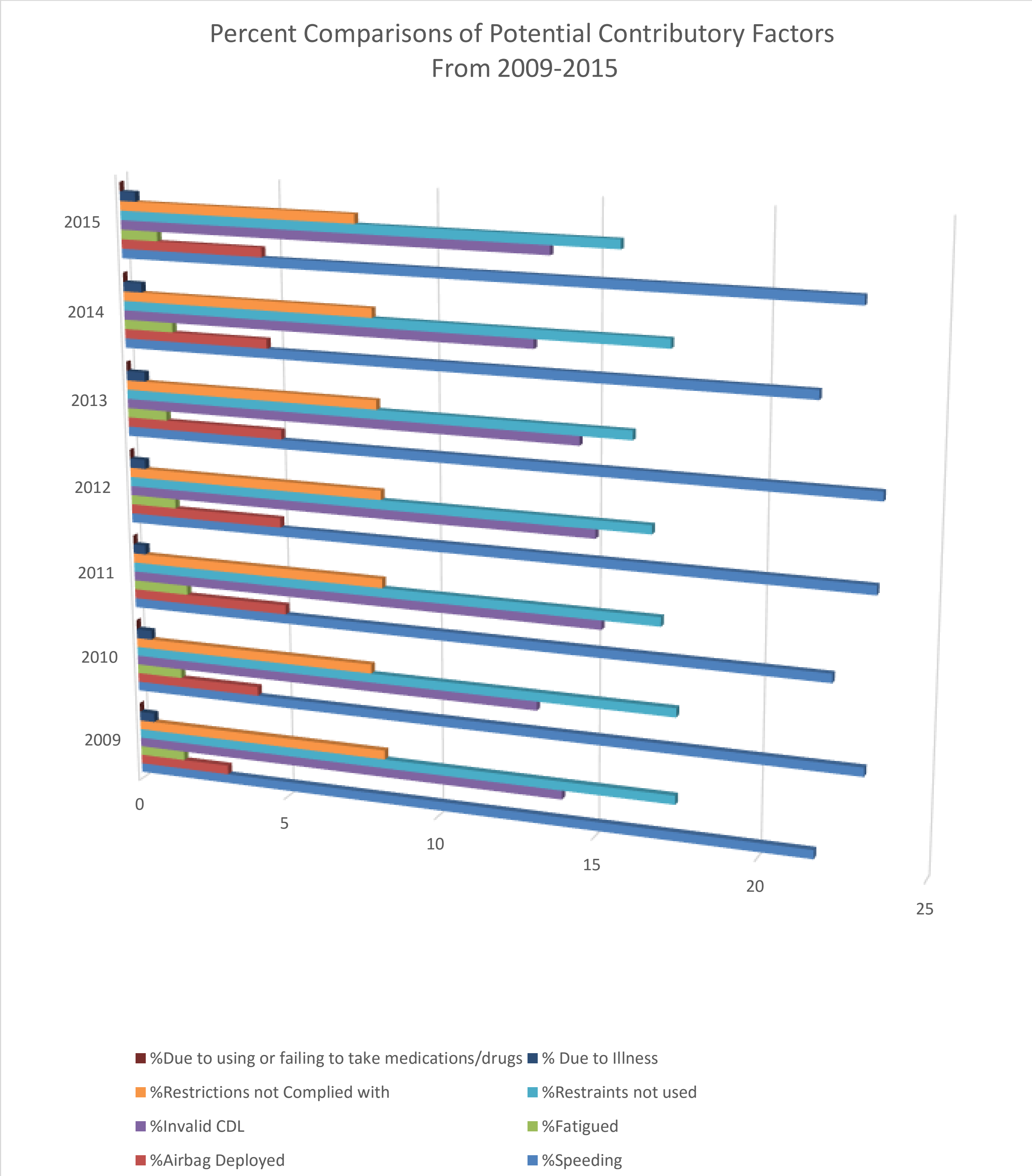


YEAR

Table 2

	%Speeding	%Airbag Deployed	%Fatigued	%Invalid CDL	%Restraints not used	%Restrictions not Complied with	% Due to Illness	%Due to using or failing to take medications/drugs
2009	21.7	3	1.5	14	17.5	8.3	0.5	0
2010	23.1	4.1	1.5	13.2	17.5	7.9	0.5	.02
2011	22.1	5.1	1.8	15.2	17	8.3	0.4	0
2012	23.3	5	1.5	15	16.7	8.3	0.5	0
2013	23.4	5.1	1.3	14.5	16.1	8.2	0.6	.02
2014	21.5	4.7	1.6	13.1	17.2	8.1	0.6	.02
2015	22.7	4.6	1.2	13.6	15.7	7.6	0.5	0
Pearson Chi-Square (df = 6)	8.067	27.081	10.725	13.006	8.030	35.932	10.725	n/a
	P = 0.233	p <0.001	p = 0.772	p = 0.043	p = 0.236	p = 0.007	p = 0.773	n/a

Figure 2



Percent Comparisons of Potential Contributory Factors
From 2009-2015
2015
2014
2013
2012
2011
2010
2009
0
5
10
15
20
25
%Due to using or failing to take medications/drugs
% Due to Illness
%Restrictions not Complied with
%Restraints not used
%Invalid CDL
%Fatigued
%Airbag Deployed
%Speeding

Table 3

Level of injury	1 No injury	2 Possible injury	3 injured, unknown severity	4 Non-incapacitating injury	5 Incapacitating injury	6 Fatal injury
Mean Age	46.03	46.04	47.47	46.31	46.83	48.66
95% Confidence Interval						
Lower Bound	45.85	45.06	44.13	45.94	45.85	48.25
Upper Bound	46.22	46.48	50.81	47.97	46.76	49.07
ANOVA					F = 2.231	p = 0.048
TUKEY			Level 6 to	1, 2, 4, 5		p < .001
Extent of Vehicle Damage	1 No Damage	2 Minor Damage	3 Functional Damage	4 Disabling Damage		
Mean Age	46.87	46.12	45.88	46.71		
95% Confidence Interval						
Lower Bound	46.25	45.77	45.54	46.51		
Upper Bound	47.48	46.47	46.23	46.90		
ANOVA					F = 7.195	p < .001
TUKEY	Extent 1 to 3	p = 0.036	Extent 2 to 4	p = 0.024	Extent 3 to 4	p < .001

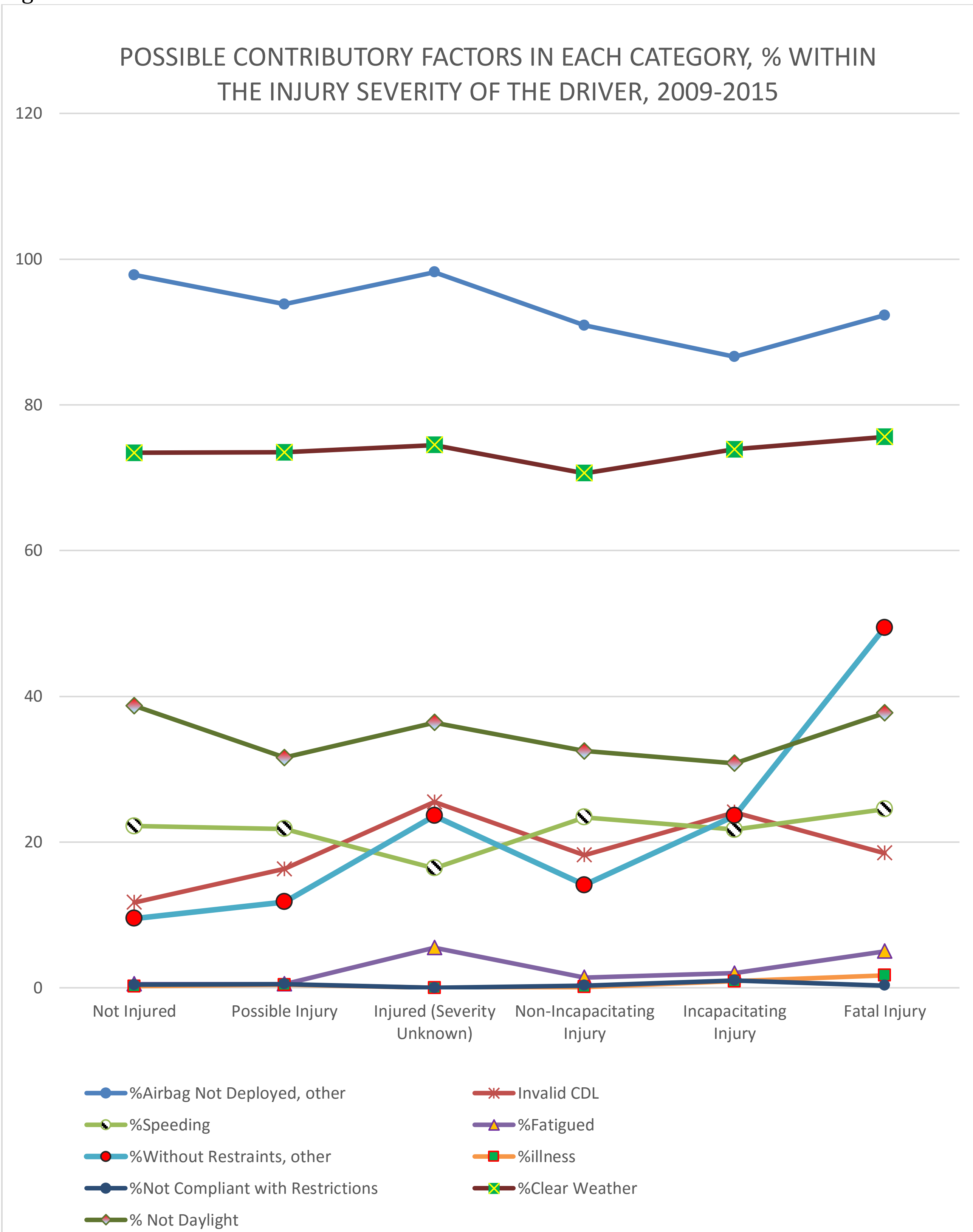
Table 4 **to follow**

Dependent Variable	**Independent Variable**	**Statistic**				**Cross Tabulation of interest**	**Expected count**	**Observed Count**
Injury Severity of the Driver	Speeding (N= 20498) Not n= 15764 Speeding n= 4734	Mann-Whitney U	36628565.0	p = .025	(2-tailed)	Speeding, Fatal Injury	907	984 (+7.82%)
Injury Severity	Air Bag Deployed (N= 20498) Not n= 19579 Deployed n= 919	Mann-Whitney U	5581357.5	p <.001	(2-tailed)	Airbag Deployed, Incapacitating Injury	46.6	137 (+65.99%)
Injury Severity	Restraint (N= 20497) Not n= 2618 Used n= 17879	Mann-Whitney U	14262385.0	p <.001	(2-tailed)	Restraint not used, fatal injury	673.9	1984 (+66.03%)
Injury Severity	Driver affected by use or failure to use drugs/medication "Normal" n= 21038 Med/drug n= 3	n/a 2010 No Injury	n/a 2013 Possible Injury	n/a 2014 Possible Injury	n/a	n/a		
Injury Severity	Condition of the Driver (N=20505) Fatigued n= 354 "Normal" n= 20151	Mann-Whitney U	1554222.0	p <.001	(2-tailed)	Driver Fatigued, Fatal Injury	52.2	199 (+73.77%)
Injury Severity	Illness or Normal (N= 20663) Illness n= 112 "Normal" n= 20151	Mann-Whitney U	538537.5	p <.001	(2-tailed)	Illness and fatally injured	16.1	61 (+73.61%)
Injury Severity	CDL Valid/Not (N= 20082) Not n= 2710 Valid n= 17372	Mann-Whitney U	20535862.0	p <.001	(2-tailed)	Invalid CDL Fatal Injury	566.1	741 (+23.60%)
Injury Severity	Drivers with Restrictions N = 2333 Not n=120 Compliant n= 2213	Mann-Whitney U	56680.0	p = .997	(2-tailed)	Not Significant		
Injury Severity	Weather Condition (N= 20498) Not Clear n= 5747 Clear n= 14751	Mann-Whitney U	42292406.0	p = .772	(2-tailed)	Not Significant		
Injury Severity	Daylight or Other (N= 20495) Other n= 7513 Daylight n= 20495	Mann-Whitney U	46669684.5	P < .001	(2-tailed)	Not Daylight, Fatal Injury	1482.9	1513 (+1.99%)
Injury Severity	Year 2009-2015 N = 27626	Kruskal Wallis Test	31.030 df = 6	p = 0.002	(2-tailed)			
Driver Fatigue or Normal	Daylight or Other N = 21393	Pearson Chi-Square	68.498 df= 1	p < .001	(2-tailed)	Daylight and Fatigued	228.9	154 (-32.72%)
						Other lighting and Fatigued	133.9	209 (+35.93%)
		Spearman *rho*	.057	p < .001	(2-tailed)			
Year	Expected fatal injury count	Observed	N = 27626			Year	Expected no injury count	Observed
2009 n= 3444	501.1	450 (-10.20%)				2009	2081.8	2116 (+1.62%)
2010 n= 3749	545.4	499 (-8.50%)				2010	2266.1	2300 (+1.47%)

2011 n= 3889	565.8	579 (+2.28%)				2011	2350.8	2306 (-1.91%)
2012 n= 4024	585.4	604 (+3.08%)				2012	2432.4	2400 (-1.33%)
2013 n= 4187	609.1	631 (+3.47%)				2013	2530.9	2448 (-3.28%)
2014 n= 3996	581.3	615 (+5.48%)				2014	2405.4	2419 (+0.06%)
2015 n= 4337	630.9	641 (+1.58%)				2015	2621.6	2710 (+3.26%)

Table 4

Figure 3



POSSIBLE CONTRIBUTORY FACTORS IN EACH CATEGORY, % WITHIN THE INJURY SEVERITY OF THE DRIVER, 2009-2015
120
100
80
60
40
20
0
Not Injured
Possible Injury
Injured (Severity Unknown)
Non-Incapacitating Injury
Incapacitating Injury
Fatal Injury
%Airbag Not Deployed, other
Invalid CDL
%Speeding
%Fatigued
%Without Restraints, other
%illness
%Not Compliant with Restrictions
%Clear Weather
% Not Daylight

Table 5

			Injury Level of the Driver						
			1	2	3	4	5	6	Total
Year	2009	Count	2116	382	3	366	127	450	3444
		Expected Count	2081.8	363.0	6.9	363.6	127.7	501.0	3444.0
	2010	Count	2300	364	9	438	139	499	3749
		Expected Count	2266.1	395.2	7.5	395.9	139.0	545.4	3749.0
	2011	Count	2306	375	9	465	155	579	3889
		Expected Count	2350.8	409.9	7.7	410.6	144.2	565.8	3889.0
	2012	Count	2400	422	6	442	150	604	4024
		Expected Count	2432.4	424.2	8.0	424.9	149.2	585.4	4024.0
	2013	Count	2448	466	13	452	177	631	4187
		Expected Count	2530.9	441.3	8.3	442.1	155.2	609.1	4187.0
	2014	Count	2419	441	6	384	131	615	3996
		Expected Count	2415.4	421.2	8.0	421.9	148.1	581.3	3996.0
	2015	Count	2710	462	9	370	145	641	4337
		Expected Count	2621.6	457.2	8.6	457.9	160.8	630.9	4337.0
Total		Count	16699	2912	55	2917	1024	4019	27626
		Expected Count	16699.0	2912.0	55.0	2917.0	1024.0	4019.0	27626.0

Table 6

Year * Level of Damage Crosstabulation

			Level of Damage				
			1	2	3	4	Total
Year	2009	Count	230	545	601	1989	3365
		Expected Count	190.8	574.4	588.3	2011.5	3365.0
	2010	Count	216	658	658	2169	3701
		Expected Count	209.8	631.8	647.1	2212.4	3701.0
	2011	Count	256	634	670	2260	3820
		Expected Count	216.6	652.1	667.9	2283.5	3820.0
	2012	Count	165	704	705	2312	3886
		Expected Count	220.3	663.4	679.4	2322.9	3886.0
	2013	Count	230	702	729	2356	4017
		Expected Count	227.7	685.7	702.3	2401.2	4017.0
	2014	Count	213	641	715	2230	3799
		Expected Count	215.4	648.5	664.2	2270.9	3799.0
	2015	Count	201	666	582	2617	4066
		Expected Count	230.5	694.1	710.9	2430.5	4066.0
Total		Count	1511	4550	4660	15933	26654
		Expected Count	1511.0	4550.0	4660.0	15933.0	26654.0

Figure 4

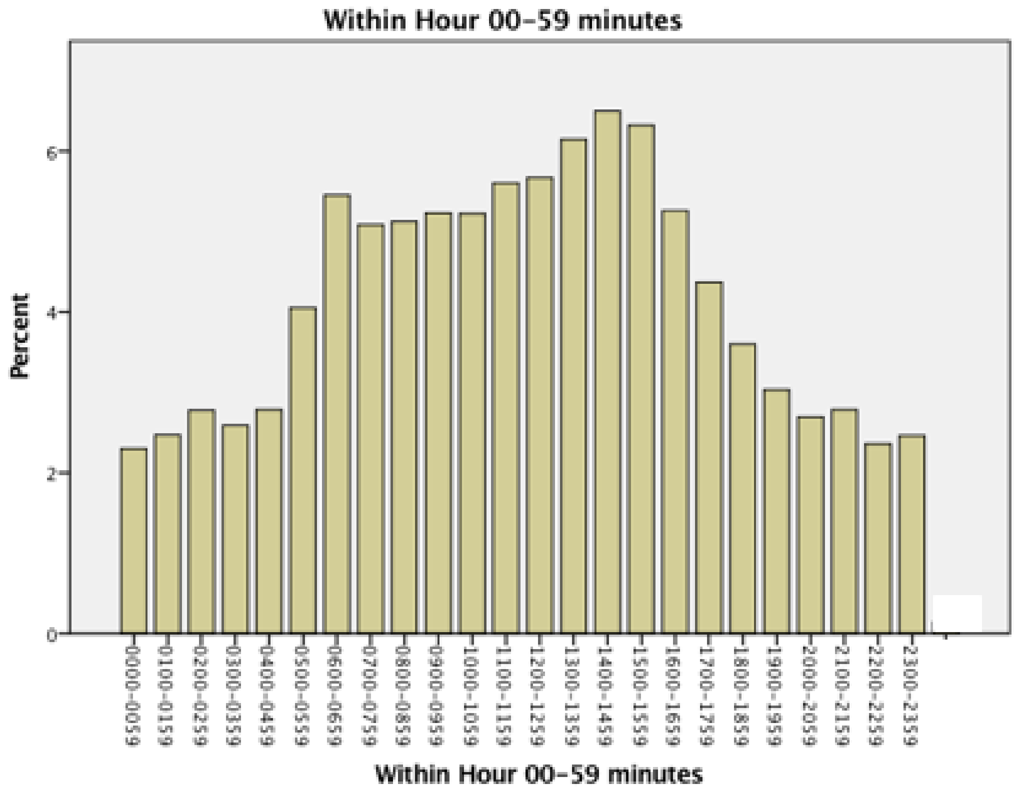

Within Hour 00-59 minutes
Percent
0
2
4
6
0000-0059
0100-0159
0200-0259
0300-0359
0400-0459
0500-0559
0600-0659
0700-0759
0800-0859
0900-0959
1000-1059
1100-1159
1200-1259
1300-1359
1400-1459
1500-1559
1600-1659
1700-1759
1800-1859
1900-1959
2000-2059
2100-2159
2200-2259
2300-2359
Within Hour 00-59 minutes

Figure 5

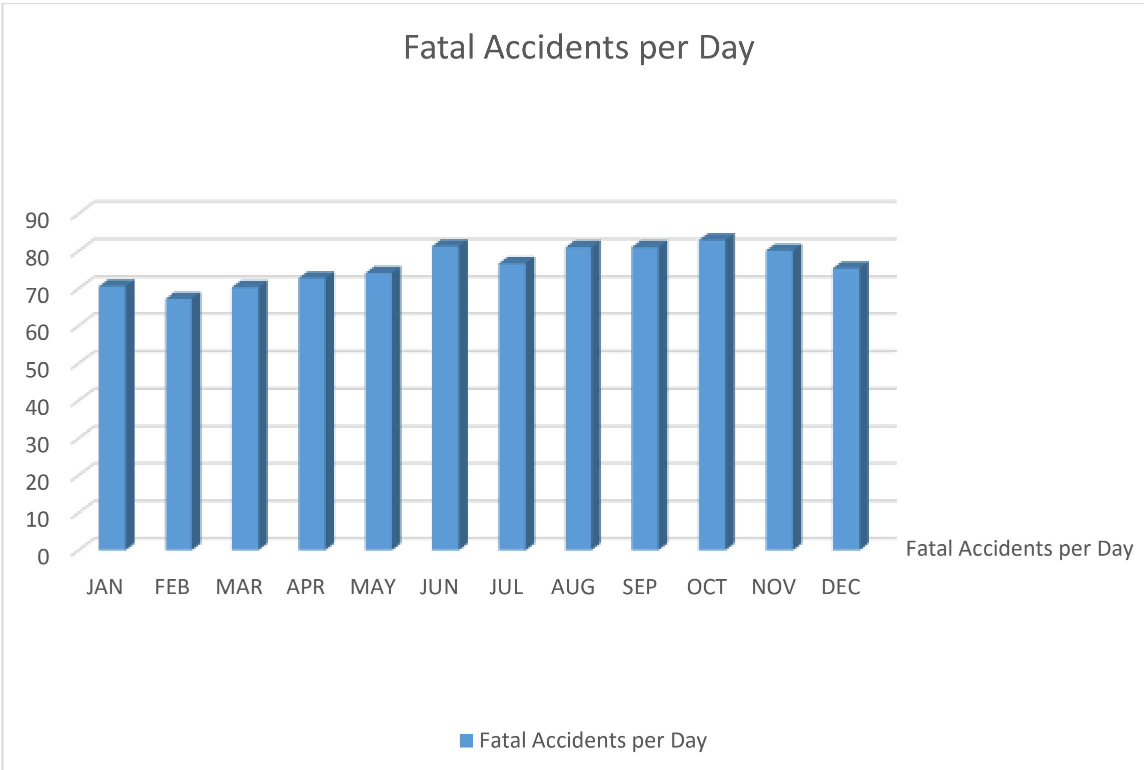
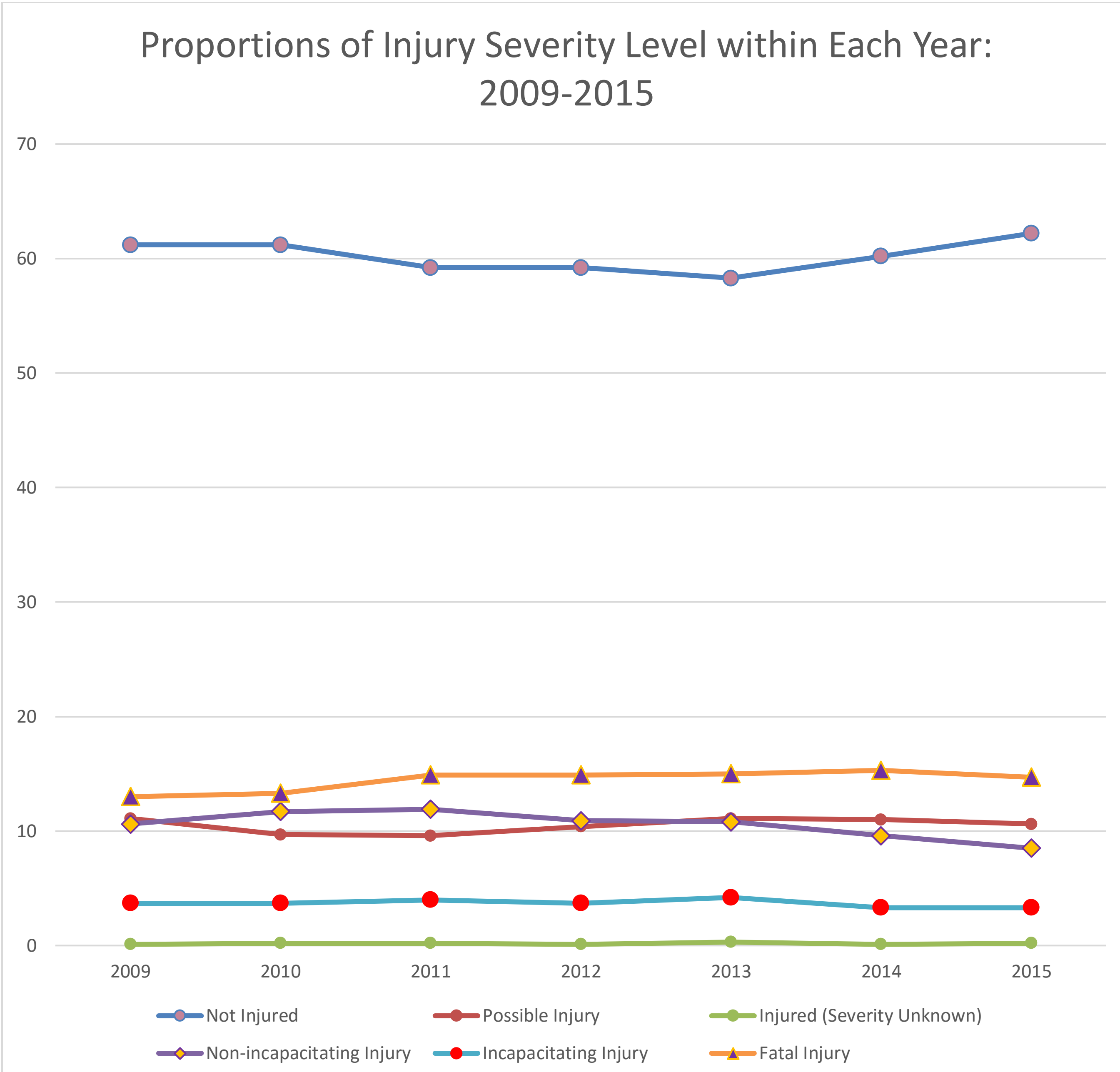


Figure 6



Proportions of Injury Severity Level within Each Year: 2009-2015
70
60
50
40
30
20
10
0
2009
2010
2011
2012
2013
2014
2015
Not Injured
Possible Injury
Injured (Severity Unknown)
Non-incapacitating Injury
Incapacitating Injury
Fatal Injury

Figure 7

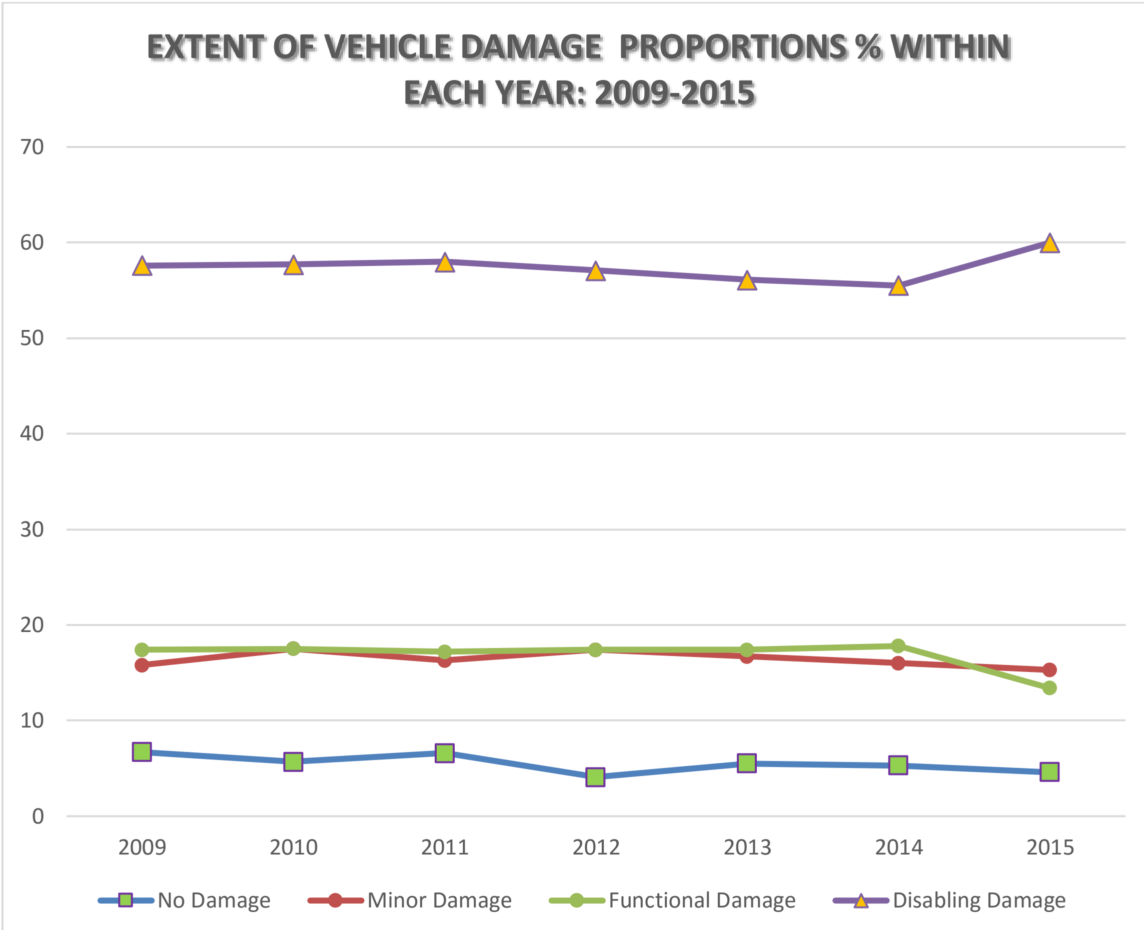


Table 7

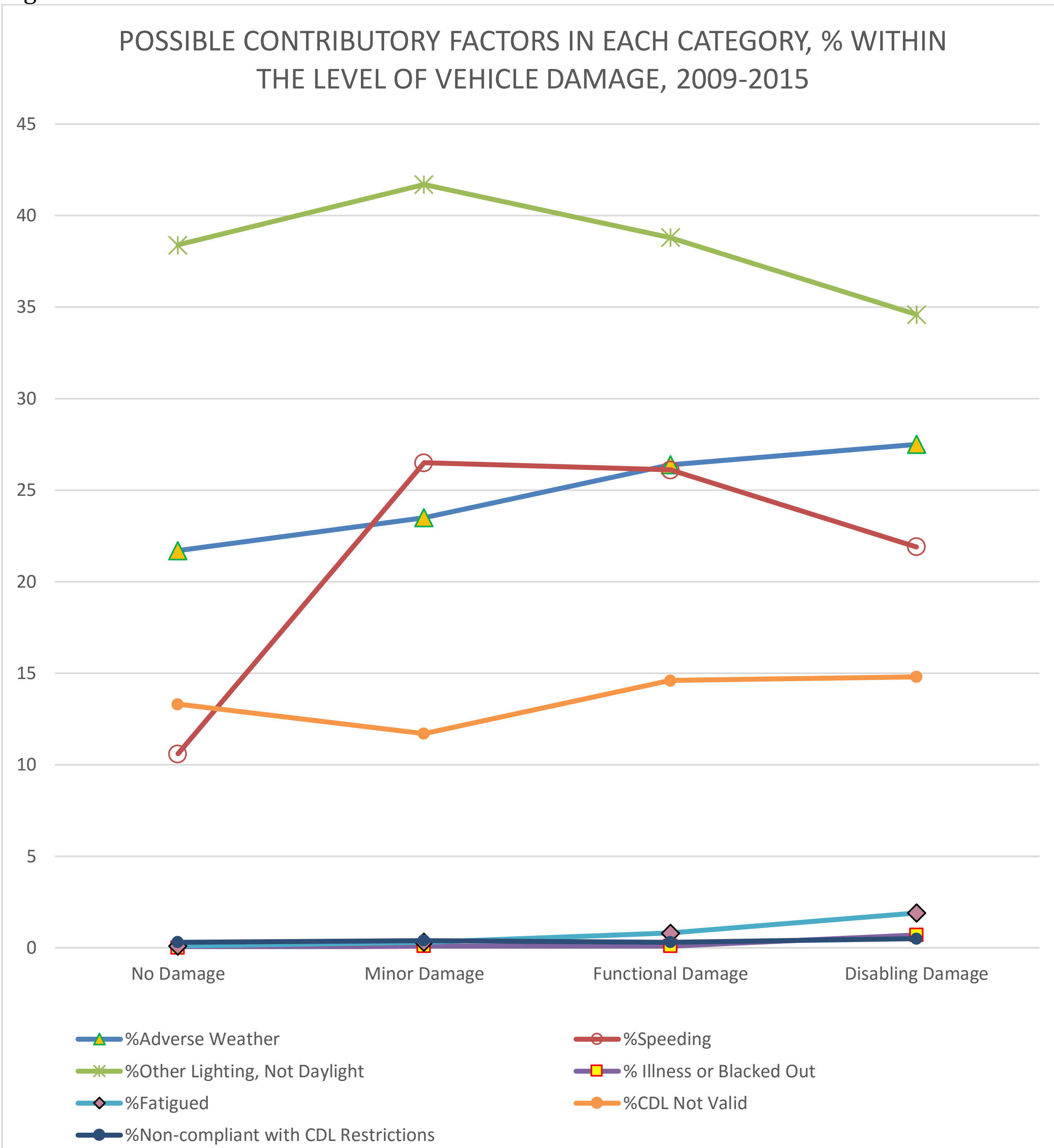
Dependent Variable	Independent Variable	Statistic					Expected count	Actual Count
Extent of Vehicle Damage	Weather Conditions (N= 20498) Clear n= 14751 Other n= 5747	Mann-Whitney U	40411878.5	p < .001	(2-tailed)	Disabling Damage Adverse weather conditions	4192.7	4386 (+4.4%)
Extent of Vehicle Damage	Speeding (N= 20498) Not n= 15764 Speeding n= 4734	Mann-Whitney U	36543198.5	p = .016	(2-tailed)	No Damage Not Speeding	1170.0	1351 (+13.40%)
Extent of Vehicle Damage	Daylight or other (N= 22666) Other n= 8308	Mann-Whitney U	56023187.5	p < .001	(2-tailed)	Daylight + Disabling Damage/No Damage	8367.7/ 791.0 4841.8/	8676 (+3.6%)/ 775 (-12.2%) 4535

	Daylight n= 14358					Other light + Disabling Damage/ No Damage	457.7	(-6.3%)/ 473 (+3.2%)
Extent of Vehicle Damage	Driver affected by use or failure to use drugs/medication "Normal" n= 21039 Med/drug n=3	n/a 2010 Disabling Damage	n/a 2013 Disabling Damage	n/a 2014 Disabling Damage	n/a	n/a	n/a	n/a
Extent of Vehicle Damage	Driver Fatigue (N= 21219) "Normal" n= 20859 Fatigued n= 360	Mann-Whitney U	2590601.0	p < .001	(2-tailed)	Disabling Damage Normal Fatigued	11838.9 202.2	11450 (-3.3%) 292 (+30.8%)
Extent of Vehicle Damage	Driver Illness (N= 20263) "Normal" n= 20151 Illness n= 112	Mann-Whitney U	890297.0	p < .001	(2-tailed)	Disabling Damage Driver with illness	63.7	86 (+25.93%) (77% of all cases with illness)
Extent of Vehicle Damage	CDL Valid (N= 24790) Not n= 3382 Valid n= 21408	Mann-Whitney U	35196104.0	p = .004	(2-tailed)	Disabling Damage Invalid CDL	1526.1	1574 (+3.04%)
Extent of Vehicle Damage	Compliant with CDL Restrictions (N= 2145) Not n= 67 Compliant n= 2078	Mann-Whitney U	67952.0	p = .700	(2-tailed)	Not Significant		
Extent of Vehicle Damage	Year 2009-2015 N = 26582	Kruskal Wallis Test Chi-Square	23.177 86.941 df = 18	p < .01 p < .001	(2-tailed)	Disabling Damage 2015	2430.5	2617 (+7.13%)
Extent of Vehicle Damage (N= 21392)	Injury Severity (N= 21392)	Spearman *Rho*	0.422	P < .001	(2-tailed)			
Year	Expected disabling damage count	Observed	N = 26582			Year	Expected no damage count	Observed

2009	2011.5	1989 (-1.12%)				2009	190.8	230 (+17.04%)
2010	2212.4	2169 (-1.96)				2010	209.8	216 (+2.87%)
2011	2283.5	2260 (-1.03%)				2011	216.6	256 (+15.39%)
2012	2322.9	2312 (-0.47%)				2012	220.3	165 (-25.10%)
2013	2401.2	2356 (-1.89%)				2013	227.7	230 (+0.01%)
2014	2270.9	2230 (-1.80%)				2014	215.4	213 (-1.11%)
2015	2430.5	2617 (+7.13%)				2015	230.5	201 (-12.80%)

Table 7

Figure 8



POSSIBLE CONTRIBUTORY FACTORS IN EACH CATEGORY, % WITHIN THE LEVEL OF VEHICLE DAMAGE, 2009-2015
45
40
35
30
25
20
15
10
5
0
No Damage
Minor Damage
Functional Damage
Disabling Damage
%Adverse Weather
%Speeding
%Other Lighting, Not Daylight
% Illness or Blacked Out
%Fatigued
%CDL Not Valid
%Non-compliant with CDL Restrictions

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